

## PATENT COOPERATION TREATY

PCT

## NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents  
United States Patent and Trademark  
Office  
Box PCT  
Washington, D.C.20231  
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 20 March 2000 (20.03.00)	
International application No. PCT/KR98/00243	Applicant's or agent's file reference 98677/KIST
International filing date (day/month/year) 07 August 1998 (07.08.98)	Priority date (day/month/year)
Applicant KIM, Hyoung, Gon et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:06 March 2000 (06.03.00)☐ in a notice effecting later election filed with the International Bureau on:2. The election ☒ was☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

# PATENT COOPERATION TREATY

## PCT

RECD 11 APR 2001

### INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference <b>98677/KIST</b>	<b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. <b>PCT/KR 98/00243</b>	International filing date (day/month/year) <b>7 August 1998 (07.08.1998)</b>	Priority Date (day/month/year)
International Patent Classification (IPC) or national classification and IPC <b>IPC<sup>7</sup>: G06T 7/20, H04N 11/00, H04N 7/00</b>		
Applicant <b>Korea Institute of Science and Technology</b>		

RECEIVED  
JUL 11 2001  
Technology Center 2600

- This international preliminary examination report has been prepared by this International Preliminary Examination Authority and is transmitted to the applicant according to Article 36.
- This REPORT consists of a total of 3 sheets, including this cover sheet.  
☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of \_\_\_\_\_ sheets.

- This report contains indications relating to the following items:

- ☒ Basis of the opinion
- ☐ Priority
- ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Lack of unity of invention
- ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Certain documents cited
- ☐ Certain defects in the international application
- ☐ Certain observations on the international application

Date of submission of the demand <b>6 March 2000 (06.03.2000)</b>	Date of completion of this report <b>28 February 2001 (28.02.2001)</b>
Name and mailing address of the IPEA/AT <b>Austrian Patent Office Kohlmarkt 8-10 A-1014 Vienna Facsimile No. 1/53424/200</b>	Authorized officer <b>WERNER</b>  Telephone No. 1/53424/357

Form PCT/IPEA/409 (cover sheet) (July 1998)

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/KR 98/00243

**I. Basis of the report****1. With regard to the elements of the international application:\***☒ the international application as originally filed☐ the description:

pages \_\_\_\_\_, as originally filed

pages \_\_\_\_\_, filed with the demand

pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_.

☐ the claims:

pages \_\_\_\_\_, as originally filed

pages \_\_\_\_\_, as amended (together with any statement) under Article 19

pages \_\_\_\_\_, filed with the demand

pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_.

☐ the drawings:

pages \_\_\_\_\_, as originally filed

pages \_\_\_\_\_, filed with the demand

pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_.

☐ the sequence listing part of the description:

pages \_\_\_\_\_, as originally filed

pages \_\_\_\_\_, filed with the demand

pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_.

**2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.**

These elements were available or furnished to this Authority in the following language \_\_\_\_\_ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).☐ the language of publication of the international application (under Rule 48.3(b)).☐ the language of the translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).**3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:**☐ contained in the international application in printed form.☐ filed together with the international application in computer readable form.☐ furnished subsequently to this Authority in written form.☐ furnished subsequently to this Authority in computer readable form.☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.**4. ☐ The amendments have resulted in the cancellation of:**☐ the description, pages \_\_\_\_\_.☐ the claims, Nos. \_\_\_\_\_.☐ the drawings, sheets/fig \_\_\_\_\_.**5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).\*\***

\* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as „originally filed“ and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

\*\* Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.  
PCT/KR 98/00243

## V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

### 1. Statement

Novelty (N)	Claims <u>1-12</u>	YES
	Claims _____	NO
Inventive step (IS)	Claims <u>1-12</u>	YES
	Claims _____	NO
Industrial applicability (IA)	Claims <u>1-12</u>	YES
	Claims _____	NO

Citations and explanations (Rule 70.7)

The following documents have been cited in the Search Report:

D1: EP0786907A  
D2: US5204749  
D3: US4472732A  
D4: JP5068241A

None of the cited patent documents disclose the detection of a moving object in a sequence of color frame images by performing color transformation, and color normalization thus emphasizing pixels belonging to the moving object, and frame delay followed by motion detection.

Therefore the subject matter according to claims 1, 6 as well as the dependent claims 2-5 and 7-12 respectively appears novel over prior art.

An inventive step is involved.

Industrial applicability is given.

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b> <b>G06K</b>	<b>A2</b>	<b>(11) International Publication Number:</b> <b>WO 00/08586</b> <b>(43) International Publication Date:</b> 17 February 2000 (17.02.00)
<b>(21) International Application Number:</b> PCT/KR98/00243 <b>(22) International Filing Date:</b> 7 August 1998 (07.08.98)  <b>(71) Applicant (for all designated States except US):</b> KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY [KR/KR]; 39-1 Hawolgok-dong, Seongbuk-ku, Seoul 136-791 (KR).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> KIM, Hyoung, Gon [KR/KR]; 12-202 Seochowoosung Apt., 1336 Seocho-dong, Seocho-ku, Seoul 137-070 (KR). AHN, Sang, Chul [KR/KR]; 204-805 Ruwon Apt., Dangsang-dong, Yougdeungpo-ku, Seoul 150-045 (KR). KIM, Nam, Ho [KR/KR]; 233-23, Pungnab2-dong, Songpa-ku, Seoul 138-042 (KR).  <b>(74) Agent:</b> CHANG, Soo, Kil; Seoul Building, 114-31 Uni-dong, Chongro-ku, Seoul 110-350 (KR).		<b>(81) Designated States:</b> DE, JP, KR, US.  <b>Published</b> <i>Without international search report and to be republished upon receipt of that report.</i>
<b>(54) Title:</b> APPARATUS AND METHOD FOR DETECTING A MOVING OBJECT IN A SEQUENCE OF COLOR FRAME IMAGES  <b>(57) Abstract</b>  An apparatus and method for detecting a moving object in a sequence of color frame images is provided. The apparatus comprises a color normalizer for normalizing color components of the color frame image to produce a normalized frame image; a color transformer coupled to the color normalizer for color transforming the normalized frame image to a color transformed frame image; the color transformed frame image having intensity levels such that colors corresponding to said moving object are emphasized; a frame delay coupled to the color transformer for delaying the color transformed frame image by one frame; and a motion detector coupled to the color transformer and the frame delay for detecting the motion of the moving object and further intensifying the intensity levels of the color transformed frame image based on the detected motion.		

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav	TM	Turkmenistan
BF	Burkina Faso	GR	Greece		Republic of Macedonia	TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's	NZ	New Zealand		
CM	Cameroon		Republic of Korea	PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

## APPARATUS AND METHOD FOR DETECTING A MOVING OBJECT IN A SEQUENCE OF COLOR FRAME IMAGES

### Technical Field:

5

The present invention relates to an apparatus and method for detecting a moving object in a motion picture, and more specifically, to an apparatus and method for detecting a face region from a motion picture by using the color and motion information of the face region.

10

### Background Art:

Detecting a face region from a motion picture is one of the prerequisite steps in face recognition. Conventional schemes for detecting a face region  
15 have not been used widely, since those schemes are affected by background images, and the size and orientation of the face.

Detection of face regions may be performed by using the information of the shape, color, or motion of the faces.

Using shape information for detecting a face region may be performed  
20 by measuring variation of gray levels and applying the measured values to *a priori* information of the face. However, the scheme should be applied only to images containing front side of a face, and the detection result is largely affected by background images, and the size and orientation of the face.

The scheme of using color information suffers from racial deviations of  
25 face colors, because the scheme detects a face region by using the inherent color of human faces. Further, the scheme requires large amount of data processing, since it uses much more information than the scheme of using shape information. However, it becomes more applicable than the scheme of using shape information, as hardware technology has recently developed.

30 The motion information may also be used for detecting face regions in

motion pictures wherein an object, i.e. a face, is moving.

Disclosure of Invention:

5 It is therefore a principal object of the invention to provide an apparatus and method for detecting a moving object wherein the detection is not affected by background images, and the size and orientation of the moving object.

It is another object of the invention to provide an apparatus and method for detecting a moving object including a face region wherein the detection may  
10 be performed faster than the prior art.

In accordance with one aspect of the present invention to achieve the aforementioned object, an apparatus for detecting a moving object in a sequence of color frame images is provided. The color frame images have a plurality of pixels, each having three color components. The apparatus comprises a color  
15 normalizer for normalizing color components of the color frame image to produce a normalized frame image, a color transformer coupled to the color normalizer for color transforming the normalized frame image to a first color transformed frame image, the first color transformed frame image having intensity levels such that pixels corresponding to said moving object are  
20 emphasized, a frame delay coupled to the color transformer for delaying the first color transformed frame image by one frame to produce a second color transformed frame image, and a motion detector coupled to the color transformer and the frame delay for detecting the motion of the moving object and further intensifying the intensity levels of the first color transformed frame  
25 image based on the detected motion.

Brief Description of Drawings:

The present invention will become more apparent upon a detailed  
30 description of the best mode for carrying out the invention as rendered below.



- 3 -

In the description to follow, references will be made to the accompanying drawings, where like reference numerals are used to identify like parts in the various views and in which:

Fig. 1 shows a block diagram of the overall system for detecting a  
5 moving object in a color motion picture in accordance with the present invention;

Fig. 2 shows a block diagram of the color normalizer 100 of Fig. 1;

Fig. 3a shows a histogram of normalized color components in a typical face image.

10 Fig. 3b shows a histogram of normalized color components in a face images modeled by using 2-dimensional Gaussian distribution function.

Fig. 4 shows a block diagram of the color transformer 200 of Fig. 1;

Fig. 5 shows results of color transformation by using GFCD modeling of a typical face image;

15 Fig. 6 shows a block diagram of the motion detection block 400 of Fig. 1.

Fig. 7 shows motion detection results of two successive images which have a rectangular object.

Fig. 8 shows motion detection results of two successive images having  
20 a human face.

#### Best Mode for Carrying out the Invention:

Fig. 1 shows a block diagram for illustrating the overall system for  
25 detecting a moving object in a color motion picture in accordance with the present invention. The system comprises a color normalizer 100 for normalizing color components of a current frame image of the color motion picture; a color transformer 200 for color transforming the normalized frame image to a color transformed frame image; a frame delay 300 for temporarily  
30 storing the color transformed frame image from the color transformer 200 to

delay the color transformed frame image by one frame; and a motion detector 400 for receiving the color transformed current and previous frame images from the color transformer 200 and the frame delay 300 and detecting the motion of the moving object. The color transformed frame image, which is  
5 produced by the color transformer, has intensity levels such that pixels corresponding to the moving object are emphasized. The motion detector 400 uses the detected motion of the moving objects to further intensify the intensity levels of pixels of the moving object.

Referring now to Fig. 2, the operation of the color normalizer 100 of  
10 Fig. 1 will be explained.

In color model of RGB color space, for example, any color information Q may be represented by three color components, i.e., red, green, and blue color components R, G, and B, having different wavelengths. In other words, the color information Q may be given by  $Q = (R, G, B)$ . A luminance value  
15 Y may be defined by sum of the three color components. The luminance value Y is a measure of a visible radiant energy which produces the sensation of brightness. In order to prevent brightness of an image from affecting the color components of an image, the color components of each pixel must be normalized by luminance value Y of the pixel.

20 Fig. 2 shows a block diagram of the color normalizer 100. The color normalizer 100 comprises a luminance extractor 130, and two normalizers 110 and 120. The luminance extractor 130 evaluates a luminance value Y by summing red, green, and blue color components R, G, and B for each pixel of a frame image, i.e.,  $Y = R + G + B$ , and outputs it. Then, the normalizer  
25 110, for example, red component normalizer receives the Y values and outputs normalized color component r by using the luminance value Y and red color component R, wherein r is given by  $(R/Y) * 255$ . Similarly, the normalizer 120, for example, green component normalizer receives the luminance value Y and outputs normalized color component g which is given by  $g = (R/Y) *$   
30 255. Hereinabove, we assumed that the luminance value has depth of 3 bits,

- 5 -

and the most bright pixel has the luminance value of 255. By the normalization, any color information  $Q$  may be represented by two normalized color components  $r$  and  $g$ , i.e.  $Q = (r, g)$ , since the three normalized color components  $r$ ,  $g$ , and  $b$  has the relationship of  $r + g + b = 255$ . In this way, 5 the color model of the normalized color space can represents  $256^2/2$  colors, while the color model of RGB color space represents  $256^3$  colors.

Fig. 3a shows histogram of normalized color components in a typical face image. In Fig. 3a, two horizontal axis represents two normalized color component values  $r$  and  $g$ , and the vertical axis represents number of pixels 10 having normalized color components of  $r$  and  $g$  in a typical face image. Distributions of the normalized color components are similar for all face images regardless of backgrounds and brightness.

Fig. 3b shows histogram of normalized color components in face image which is modeled by 2-dimensional Gaussian distribution function. In this 15 embodiment of the invention, the modeling is performed by using 2-dimensional Gaussian distribution as shown in Fig. 3b. The Gaussian model for color distribution in face images is called Generalized Face Color Distribution (GFCD). GFCD is defined by mean  $m$  and variance  $\Sigma^2$ , in other words, GFCD is represented by  $GF(m, \Sigma^2)$ . In this representation,  $m = (/r, /g)$  is the center 20 point of the 2-dimensional Gaussian distribution, wherein  $/r$  and  $/g$  are mean values of normalized color components for all pixels in a face image.  $\Sigma^2$  represents a covariance matrix of normalized color components in a face image. In a preferred embodiment, a GFCD for face images may have  $m = (105, 95)$  and  $\Sigma^2$  of  $\sigma_r = 20$  and  $\sigma_g = 15$ . By using the GFCD model, an input color 25 image containing a face may be transformed to a gray-level image where pixels having color of the face are emphasized.

The color transformation using a color distribution model transforms normalized color components of pixels to values which represent the proximity of the color components to the mean  $m = (/r, /g)$  of the Gaussian distribution 30 in the normalized color space. The color transformation is defined as follows:

- 6 -

$$Z(x, y) = GF\left(\frac{f}{r}(x, y), \frac{f}{g}(x, y)\right) \quad (x, y) \in I \quad \text{Eq. 1}$$

,wherein (x, y) is a coordinate of a pixel in the face image, g(x, y) and r(x, y) are normalized color components of the pixel at the coordinate (x, y), and GF() is Generalized Face Color Distribution function. The color transformation using GFCD produces values which are proportional to the proximity of the  
5 color of the pixel to a human face color.

Referring to Figs. 4 and 5, the operation of the color transformers 200 of Fig. 1 will be explained.

Fig. 4 shows a block diagram of the color transformer 200. Color transformer 200 comprises blocks 210 and 220, two normalization block 230  
10 and 240, and output block 250. Block 210 receives the normalized color component r from the normalizer 110 and compares it with  $\sigma_r$ , which is predetermined in accordance with a particular GFCD model. If the normalized color component r is within three times of  $\sigma_r$  around  $/r$ , then, the block 210 outputs  $r' = |r - /r|$ . Otherwise, the block 210 outputs a very large value  
15 in order to make  $Zr = 0$ . Blocks 230 receives the output value  $r'$  and outputs transformed value  $Zr$  by referring to a look-up table LUT which contains 1-dimensional normalized Gaussian number  $GF(0, \sigma_r^2)$ . Similarly, block 220 receives the normalized color component g and compares it with  $\sigma_g$ . If the normalized color component g is within three times of  $\sigma_g$  around  $/g$ , then, the  
20 block 220 outputs  $g' = |g - /g|$ . Otherwise, the block 220 outputs a very large value in order to make  $Zg = 0$ . The block 240 receives the output value  $g'$  and outputs transformed value  $Zg$  by referring to a look-up table LUT which contains 1-dimensional normalized Gaussian number  $GF(0, \sigma_g^2)$ . Output block 250 receives  $Zr$  and  $Zg$  values and evaluates  $Z = (Zr * Zg) * 255$  and outputs  
25 Z. Fig. 5 shows results of color transformation by using GFCD modeling of a typical face image. As can be seen in the result image of Fig. 5, areas having human face color are emphasized.

If any background images have color which is similar to the color of

- 7 -

human face, the above method may emphasize those background images as well as face area. In order to overcome this problem, the present method uses motion information of human face. In general, only the human face area is moving while background images remain still. Thus, the human face area may be outstandingly distinguished from background images, if motion information of the face area is utilized.

Two methods for extracting motion information from two successive frame images are well known in the art. They are region based method and feature point based method. Most applications in the art use the region based method rather than the feature point based method, since the latter generally requires post-processing which uses interpolation technique.

In a typical region based method, the inter-frame differences of intensity levels of pixels adjacent a particular pixel are summed in order to measure the motion of the particular pixel. This method is known as Accumulated Difference Measure (ADM) method. Since the ADM method uses the summation of intensity differences of neighbor pixels, it detects a motion robustly against small noisy change of neighbor pixels. However, pixels having small differences are ignored by averaging effect, and the measurements are largely affected by the determination of threshold value.

Thus, the present invention preferably performs motion detection by counting pixels whose inter-frame differences are larger than a threshold value in a window having predetermined size. This motion detection measure will be called Unmatching Pixel Count (UPC) measure and may be written as follows:

$$UPC(x, y, t) = \sum_{i=x-N}^{i=x+N} \sum_{j=y-N}^{j=y+N} U(i, j, t) \quad Eq. 2$$

$$U(i, j, t) = \begin{cases} 1, & \text{if } |Z(i, j, t) - Z(i, j, t-1)| > Th \\ 0, & \text{otherwise} \end{cases}$$

wherein Th is a threshold value for determining whether the intensity values of

- 8 -

pixels in two successive frame images are matched. In the UPC method, since matching is tested in a pixel by pixel manner and the results are accumulated, the averaging effect is reduced such that overlapping area causing a small intensity change is clearly captured.

5 In order to detect motion of a color image, the color information explained hereinabove may be used. It may be recognized by those skilled in the art that the intensity level of each pixel in the color transformed image, which was transformed by using the color transformation method of GFCD modelling, represents a probability that the pixel is in a face area. The color  
10 information of the color transformed image may be incorporated in Eq. 2 by weighting the counts with the intensity level of the pixel of the color transformed image. This new motion detection measure will be referred to as Weighted Unmatching Pixel Count (WUPC). The WUPC(x, y, t) is evaluated by performing fuzzy-AND operation between the UPC measure UPC(x, y, t)  
15 and the intensity level of the color transformed image Z(x, y, t). The WUPC measure is given by following equation:

$$WUPC(x, y, t) = Z(x, y, t) \otimes \sum_{i=x-N}^{i=x+N} \sum_{j=y-N}^{j=y+N} U(i, j, t) \quad Eq. 3$$

$$U(i, j, t) = \begin{cases} 1, & \text{if } |Z(i, j, t) - Z(i, j, t-1)| > Th \\ 0, & \text{otherwise} \end{cases}$$

20 wherein the operator  $\otimes$  is fuzzy-AND operator. This WUPC measure emphasizes motion of the pixels having color which is similar to color of a human face, while deemphasizing motion of the other pixels, i.e., pixels of background images.

In Eq. 3, the threshold value Th may be obtained adaptively by using the  
25 transformed image value Z(x, y, t) for each pixel. In other words, the Th becomes small for pixels which are in a face area and large for other pixels. In this way, the WUPC measure is more sensitive to motion of pixels in a face area than motion of the other pixels, such that even small motion of face area may be detected. In a preferred embodiment of the present invention, the  
30 threshold Th may be obtained by using Sigmoid function as follows:

Slope of Sigmoid function becomes steep as Q is lowered. Thus, Sigmoid

- 9 -

$$Th(Z) = \frac{255}{1 + e^{\frac{Z(x,y,t) - 255/2}{Q}}} \quad Eq. 4$$

function is a lot like a step-function shape for small Q. It is appropriate to use Sigmoid function as a function for determining threshold Th of Eq. 3, since the Sigmoid function outputs small threshold Th for a large input value and large Th for small input value. Further, the Sigmoid function is nonlinear in that the function does not respond abruptly to maximum or minimum input values. This method for adaptively counting unmatched pixels will be called Adaptive Weighted Unmatching Pixel Count (AWUPC) measure.

Fig. 6 shows a block diagram of the motion detection block 400 of Fig. 1. The motion detection block 400 comprises line buffers 410 and 420 for temporarily storing color transformed images and outputting intensity levels of pixels in a window of a predetermined size; an adaptive threshold value generator 440 for generating threshold th in response to intensity level of a central pixel in the window; an unmatching pixel value generator 430 for receiving the threshold Th and present and previous frames of the color transformed image from line buffers 410 and 420 to determine whether the pixels in the window of the present frame match with the pixels in the window of the previous frame by evaluating unmatching pixel value U(x, y, t) of Eq. 3; an unmatching pixel counter 450 for counting the pixels which are determined to be unmatching pixels in the unmatching pixel generator 430; and a fuzzy-AND operator 460 for performing fuzzy-AND operation on the outputs of the unmatching pixel counter 450 with the intensity level Z(x, y, t) of the pixel of the color transformed image from the line buffer 420. The line buffer 420 outputs intensity level Z(i, j, t) in a window of the present frame, while the line buffer 410 outputs intensity level Z(i, j, t-1) in a window of the previous frame of the color transformed image. The window size is (2N + 1) x (2N + 1) such that the line buffers 410 and 420 output intensity levels of (2N + 1) x (2N + 1) pixels. The threshold value generator 440 receives the intensity level of the central pixel Z(x, y, t) among the window of the present frame and evaluates a threshold value Th according to Eq. 4. The unmatching pixel generator 430 receives outputs from the line buffers 410 and threshold value

- 10 -

Th from the threshold value generator 440. Then, the unmatching pixel generator 430 evaluates the  $u(i, j, t)$  of Eq. 3 for a central pixel  $Z(x, y, t)$  of the window. The unmatching pixel counter 450 receives the outputs of the unmatching pixel generator 430 and counts the number of unmatching pixels.

- 5 The fuzzy-AND operator 460 outputs a color motion information by performing a fuzzy-AND operation between the intensity level of the central pixel  $Z(x, y, t)$  from the line buffer 420 and the outputs from the unmatching pixel counter 450.

Referring to Figs. 7 and 8, motion detection results of the present invention will be compared with those of the prior art. Fig. 7 shows motion detection results of two successive images which have a rectangular object. Fig. 7a shows the first images having a rectangular object with background images. Pixels in the rectangular object of Fig. 7a have random gray levels of 200 - 230, while the gray levels of pixels in the background images are random values of 0 - 30. Fig. 7b shows the second image wherein the rectangular object is moved by 50 pixels in x and y directions. Fig. 7c shows the motion detection results according to the conventional ADM method. The areas, whose inter-frame differences of intensity levels are large, are emphasized. However, those areas where the rectangular objects of the two subsequent images are overlapped are not emphasized. Thus, the motion is not well detected by the conventional ADM method when the two objects of subsequent frames are overlapped. Fig. 7d shows a motion detection result according to the UPC measure. In Fig. 7d, those areas where the rectangular objects of the two subsequent images are overlapped are also emphasized. The UPC measure can detect motion of a moving object better than the ADM method, since it is able to detect overlapping areas of a moving object. Fig. 7e shows motion detection result according to the WUPC measure. The areas of the moving object having a desired color in the first image are emphasized. Fig. 7f shows the motion detection results by using AWUPC measure according to the present invention. Fig. 8 shows motion detection results of two successive images having a human face. Figs. 8a shows GFCD color transformed image of the first images having a human face with background images. Fig. 8b shows GFCD color transformed image of the second image wherein the human face is moved



- 11 -

slightly. Fig. 8c shows the motion detection results according to the conventional ADM method. The motion is not well detected by the conventional ADM method as shown in Fig. 8c. Fig. 8d shows a motion detection result according to the UPC measure. Figs. 8e and 8f respectively  
5 show motion detection result according to the WUPC measure and AWUPC measure in accordance with the present invention.

## Claims:

1. An apparatus for detecting a moving object in a sequence of color frame images, said color frame image having a plurality of pixels, each pixel having  
 5 three color components, comprising:
  - a color normalizer for normalizing color components of the color frame image to produce a normalized color frame image;
  - a color transformer coupled to the color normalizer for color transforming the normalized color frame image to a first color transformed  
 10 frame image, said first color transformed frame image having intensity levels such that pixels corresponding to said moving object are emphasized;
  - a frame delay coupled to the color transformer for delaying the first color transformed frame image by one frame, said delayed first color transformed frame image being a second color transformed frame image; and  
 15 a motion detector coupled to the color transformer and the frame delay for detecting the motion of the moving object and further intensifying the intensity levels of said first color transformed frame image based on the detected motion.
- 20 2. The apparatus of Claim 1, wherein each pixel of the first color transformed frame image has an intensity level which is proportional to the proximity of the normalized color components of the pixel to the normalized color components of said moving object.
- 25 3. The apparatus of Claim 2, wherein the intensity level of said each pixel of the first color transformed frame image and the normalized color components of the pixel have a relationship as follows:

$$Z(x, y) = \frac{f: R^2 \rightarrow R^1}{GF(r(x, y), g(x, y))} \quad (x, y) \in I$$

wherein (x, y) is a coordinate of said pixel in the normalized frame image, r(x, y) and g(x, y) are normalized color components of the pixel at the coordinate  
 30 (x, y), and GF( ) is a 2-dimensional Gaussian distribution function.

- 13 -

4. The apparatus of Claim 1, wherein said motion detector comprises means for detecting the motion of each pixel by counting pixels adjacent said each pixel whose intensity level differences between said first and second color transformed frame images are larger than a threshold value, and
- 5 wherein said intensity level of each pixel are further intensified by weighting said intensity level in accordance with said detected motion of said each pixel.
5. The apparatus of Claim 4, wherein said weighting is performed by
- 10 fuzzy-AND operating said intensity level with said detected motion for said each pixel.
6. The apparatus of Claim 4, wherein said threshold value is obtained by using a Sigmoid function as follows:
- $$Th(Z) = \frac{255}{1 + e^{\frac{Z(x, y, t) - 255/2}{Q}}}$$
- 15 wherein  $Z(x, y, t)$  is the intensity level of a pixel and  $Q$  is a predetermined parameter.
7. A method of detecting a moving object in a sequence of color frame images, said color frame image having a plurality of pixels, each pixel having
- 20 three color components, comprising steps of:
- normalizing color components of the color frame image to produce a normalized frame image;
- color transforming the normalized frame image to a first color transformed frame image, said first color transformed frame image having
- 25 intensity levels such that pixels corresponding to said moving object are emphasized;
- delaying the first color transformed frame image by one frame, said delayed first color transformed frame image being a second color transformed frame image; and
- 30 detecting the motion of the moving object and further intensifying the

- 14 -

intensity levels of said first color transformed frame image based on the detected motion.

8. The method of Claim 7, wherein each pixel of the first color transformed frame image has an intensity level which is proportional to the proximity of the normalized color components of the pixel to the normalized color components of said moving object.

9. The method of Claim 8, wherein the intensity level of said each pixel of the first color transformed frame image and the normalized color components of the pixel have a relationship as follows:

$$Z(x, y) = GF(r(x, y), g(x, y)) \quad (x, y) \in I$$

$f: R^2 \rightarrow R^1$

wherein  $(x, y)$  is a coordinate of said pixel in the normalized frame image,  $r(x, y)$  and  $g(x, y)$  are normalized color components of the pixel at the coordinate  $(x, y)$ , and  $GF()$  is a 2-dimensional Gaussian distribution function.

15

10. The method of Claim 7, wherein said motion detecting step comprises a step of detecting the motion of each pixel by counting pixels adjacent said each pixel whose intensity level differences between said first and second color transformed frame images are larger than a threshold value, and

20 wherein said intensity level of each pixel is further intensified by weighting said intensity level in accordance with said detected motion of said each pixel.

11. The method of Claim 10, wherein said weighting is performed by fuzzy-  
25 AND operating said intensity level with said detected motion of said each pixel.

12. The method of Claim 10, wherein said threshold value is obtained by using a Sigmoid function as follows:

$$Th(Z) = \frac{255}{1 + e^{\frac{Z(x, y, t) - 255/2}{\sigma}}}$$

- 15 -

wherein  $Z(x, y, t)$  is the intensity level of a pixel and  $Q$  is a predetermined parameter.

1/5

FIG. 1

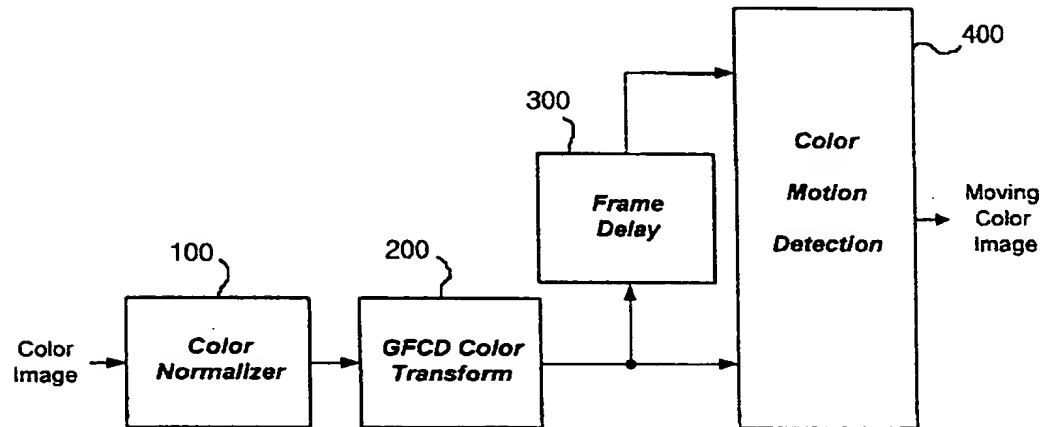
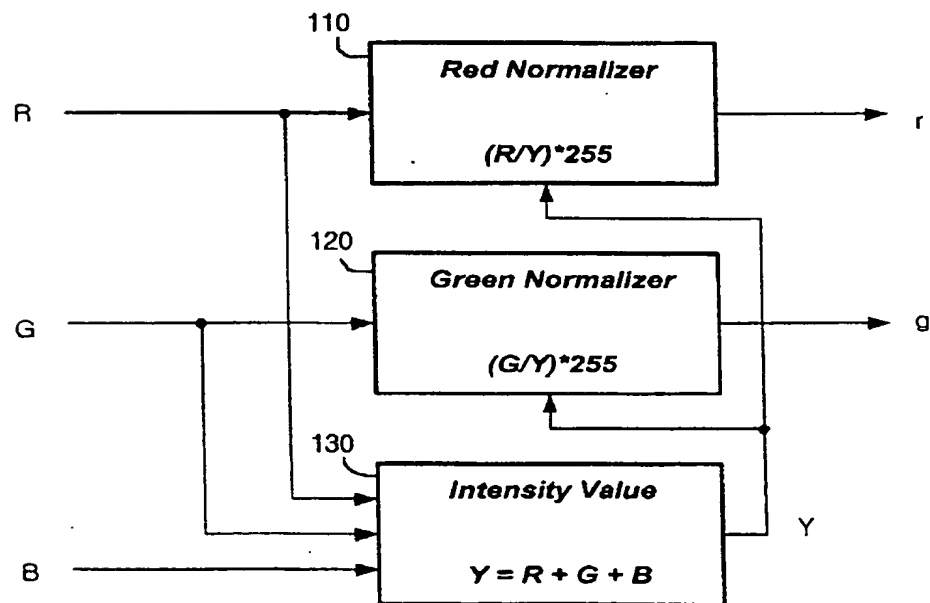


FIG. 2



2/5

FIG. 3a

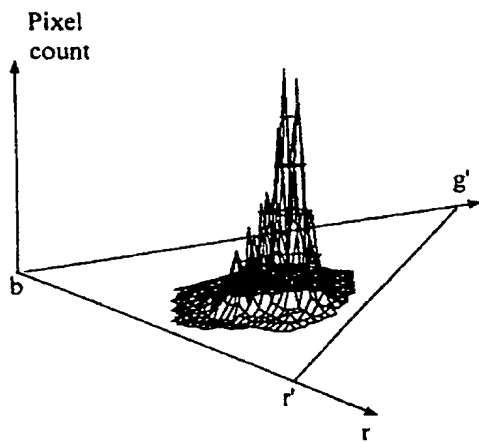


FIG. 3b

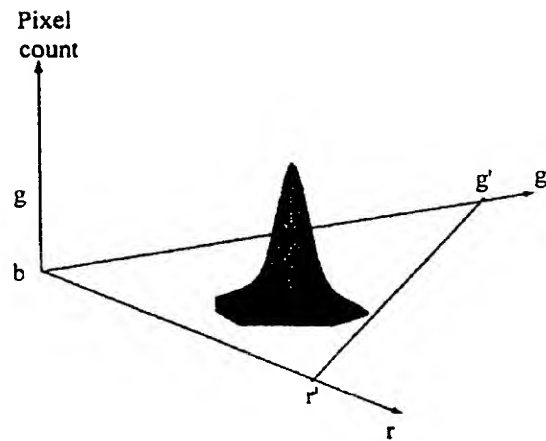
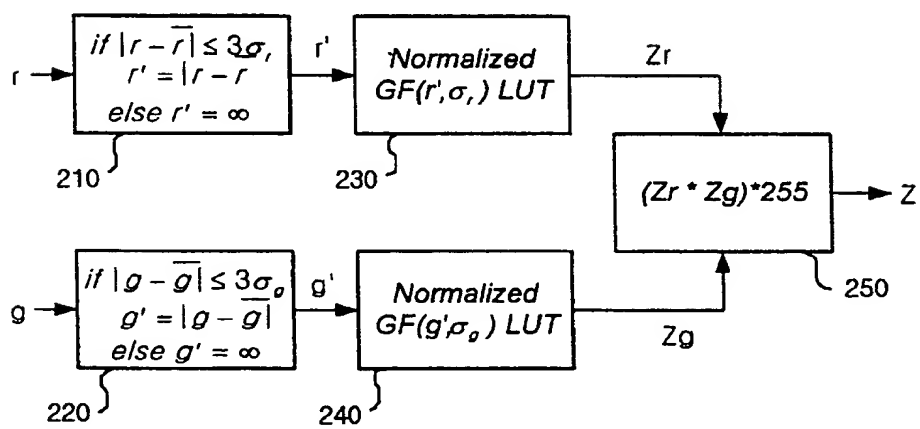


FIG. 4



3/5

FIG. 5a



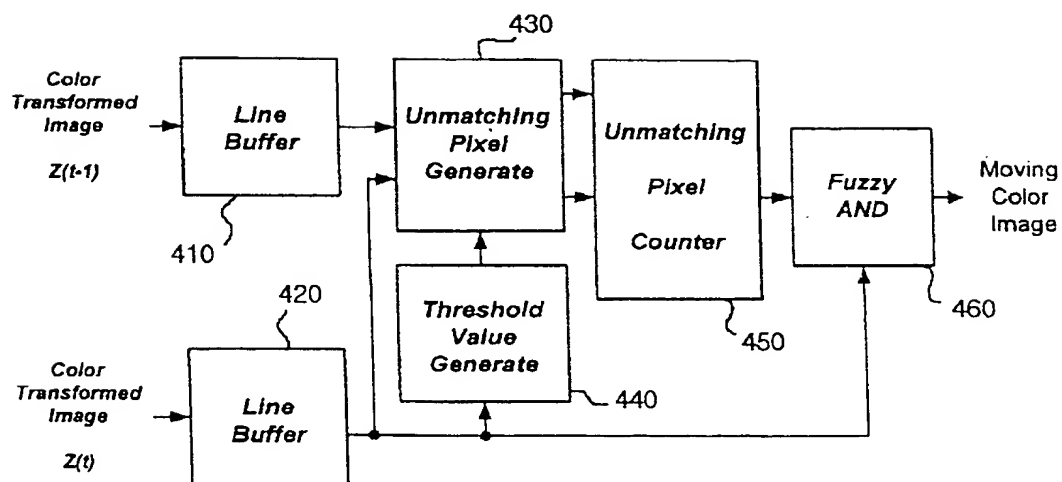
FIG. 5b



FIG. 5c



FIG. 6





4/5

FIG. 7a

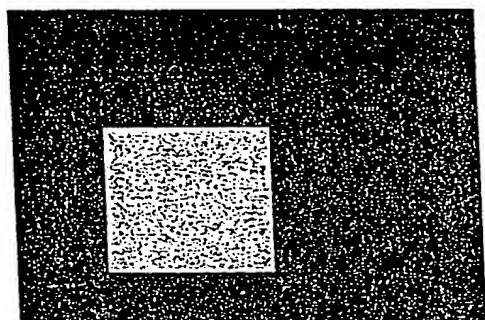


FIG. 7b

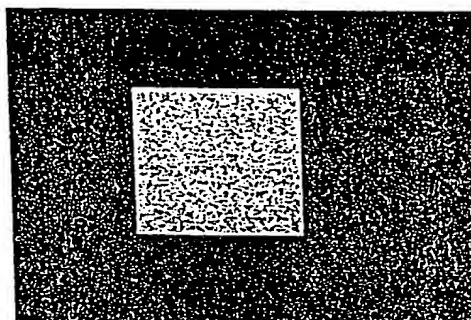


FIG. 7c

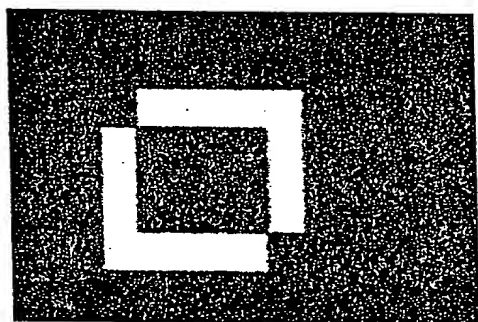


FIG. 7d

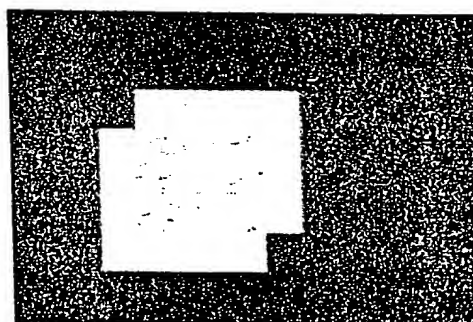


FIG. 7e

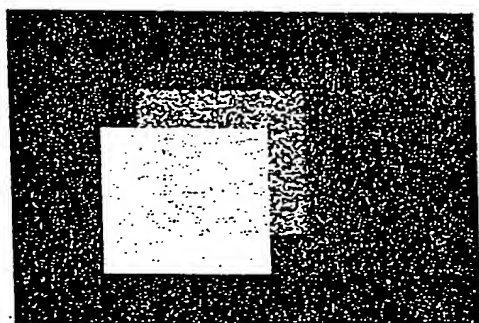
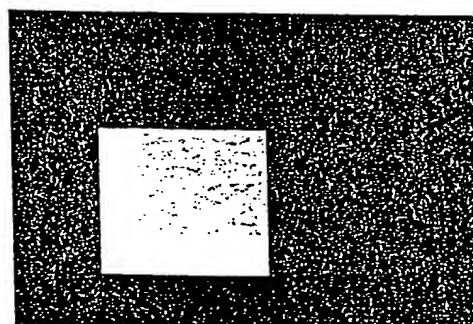


FIG. 7f



5/5

FIG. 8a



FIG. 8b



FIG. 8c

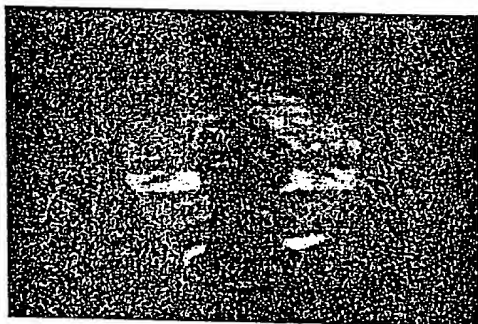


FIG. 8d

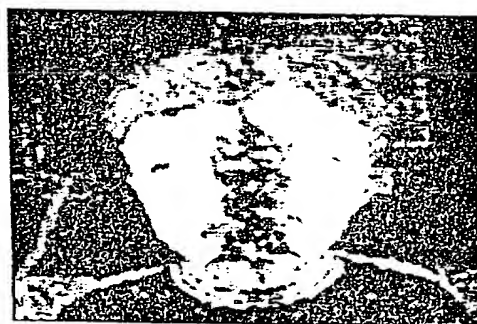


FIG. 8e



FIG. 8f

